Design of the data acquisition system for the transition radiation detector prototype

Hui Wang[a], Dong Wang[a,*], Ran Chen[a] , Kai Chen[a], Muxian Li[a], Jieyu Zhu[b], Xiwen Liu[c], Cong Dai[c], Fan Jiang[c], Ni Fang[a], Shiqiang Zhou[a], Zhuo Zhou[a] , Hongbang Liu[c] , Huijun Hu[c], and Xiangming Sun[a]

** E-mail: dongwang@ccnu.edu.cn*

a PLAC, Key Laboratory of Quark & Lepton Physics (MOE), Central China Normal University, Wuhan 430079, China

b Institute of modern physics, Chinese Academy of Sciences, Lanzhou, 730000, China

c Guangxi Key Laboratory for Relativistic Astrophysics, School of Physical Science and Technology, Guangxi University, Nanning 530004, China

Abstract

The Transition Radiation Detector (TRD) of the High Energy Cosmic Radiation Detection facility (HERD) utilizes the relationship between high-energy charged particle transition radiation and the Lorentz factor to calibrate the energy of TeV-band protons in HERD calorimeters. It can also independently conduct X-ray observation and monitor Gamma-Ray Bursts . The TRD mainly consists of detector units, front-end electronics, and data acquisition system. The data acquisition system is responsible for the overall power management of the TRD, communication and triggering between the TRD and HERD, data processing of the detector units, control of multiple modules within the TRD, and in-orbit operation of the whole TRD. Here we report a prototype of the TRD data acquisition system, which connects six front-end circuit boards, six high-voltage circuit boards, a turntable device, HERD triggering subsystem, and HERD electronics. It adopts a structure with separate data and electrical components, with the power sections of the front-end electronics, high-voltage, turntable device, and data acquisition system designed as power circuit boards, and the FEE data transmission and telemetry, triggering, main control, storage, and communication designed as data circuit boards. We tested our data acquisition system prototype at the European Organization for Nuclear Research, and the results show that the system can meet the requirements of the TRD prototype in terms of power, communication, data processing, and overall control. We also demonstrate that the data acquisition system has been redundantly designed to enhance adaptability.

Project background

High Energy Cosmic Radiation Detection facility (HERD) is a new generation large-scale international space astronomy and particle astrophysics experiment, which is scheduled to be carried on board the Chinese Space Station around 2027 and is expected to operate for more than 10 years, as shown in Fig. 1(a). HERD has three core scientific objectives, the first is to search for dark matter with higher sensitivity. The second is to investigate the origin and physics of cosmic rays. The third is to conduct wide-field high-energy gamma-ray observation and monitoring.

Transition Radiation (TR) is generated when high-energy charged particles traverse interfaces between materials with different dielectric constants. By detecting the energy of X-ray photons produced by TR, the Lorentz factor of the incident charged particles can be deduced inversely. Combining this with the charge information of the incident charged particles allows for the determination of the incident particle's momentum. Therefore, the measurement of the Lorentz factor by the Transition Radiation Detector (TRD) of HERD can serve as a calibration factor for the energy of HERD's calorimeter, enabling the absolute calibration of TeV-band proton energy in the calorimeter. Fig. 1(b) is a three-dimensional view of the TRD.

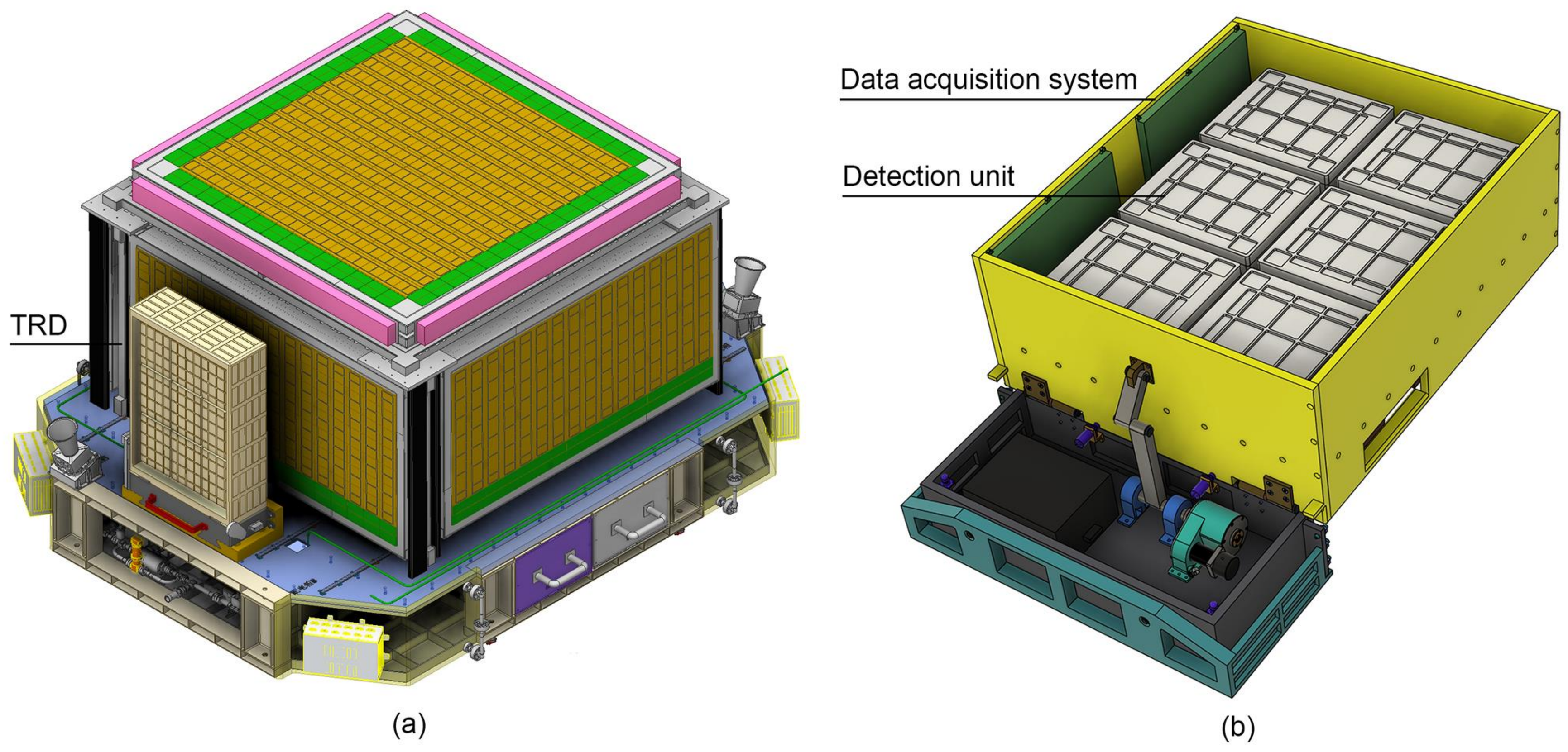

Fig. 1. (a) is a 3D image of the HERD payload, with the TRD installed on the outer side of the HERD payload, (b) shows a 3D image of the TRD lying flat.

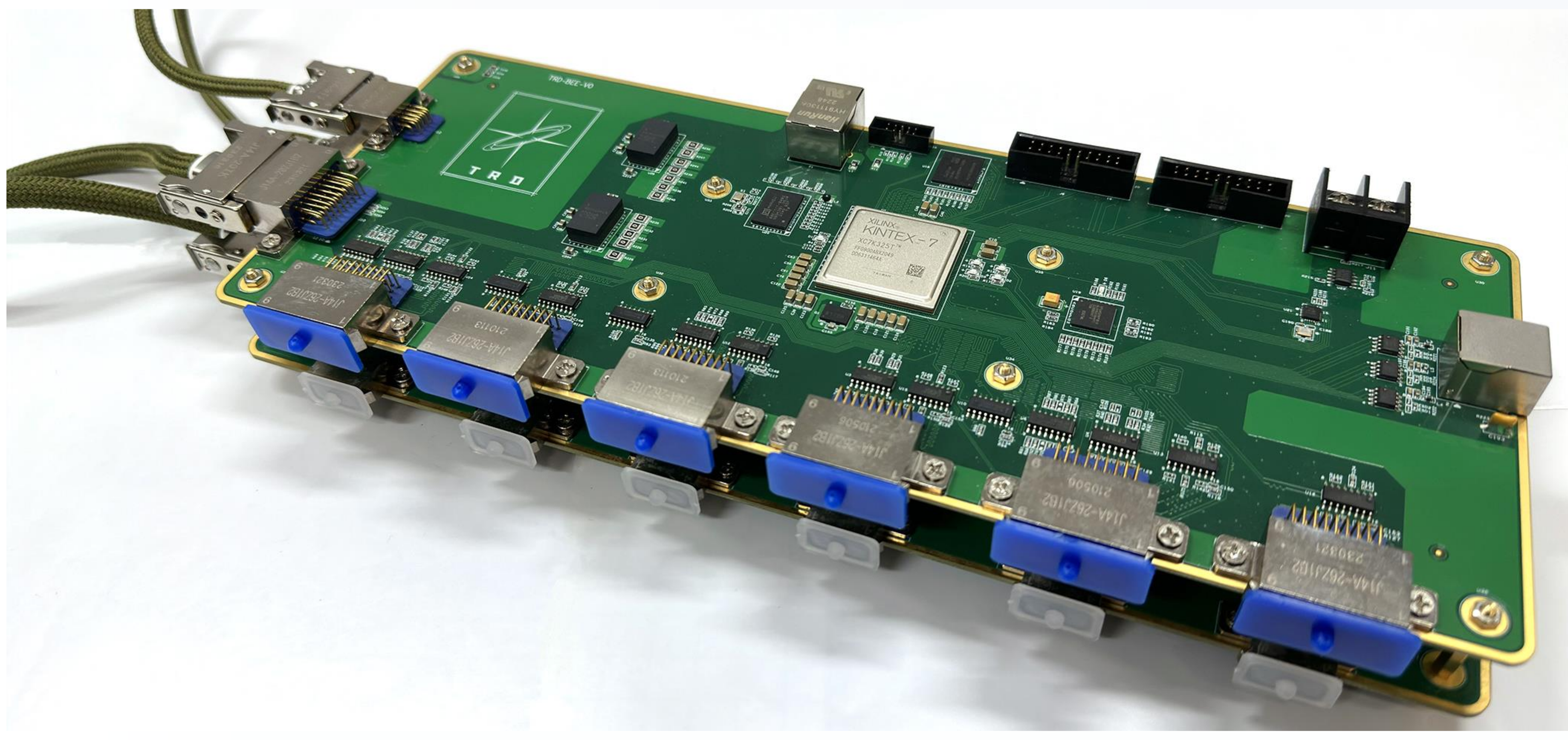

Fig. 2. The upper layer is the data circuit board and the lower layer is the power circuit board, and the two boards are connected to each other by flexible connecting wires.

TRD data acquisition system prototype

TRD primarily consists of detection units, front-end electronics, and data acquisition system. The data acquisition system is mainly responsible for the overall power management of the TRD, communication and triggering between the TRD and HERD, data processing of detector units, control of multiple modules within the TRD, and on-orbit operations of the whole TRD The prototype of the data acquisition system is composed of two circuit boards with a planar size of 310 mm × 120 mm, as shown in Fig. 2. The data circuit board is responsible for the control and telemetry of the various sub-modules of the TRD, real-time calculation, storage and encoding of detector data, external command parsing, and data transmission. The power circuit board converts the bus 100 V power supply into suitable power for various sub-modules and the data acquisition system, and also has power management functions, with power supply to various sub-modules controlled by the data circuit board. Both circuit boards need to be connected to six front-end circuit boards, six high-voltage circuit boards, and a turntable device. The data circuit board is connected to the HERD communication subsystem and the triggering subsystem, and the power board is connected to the HERD power bus.

Beam experiment

We tested the prototype of the TRD at the European Organization for Nuclear Research, as shown in Fig. 3. The front-end circuit board placed near the detection unit to reduce transmission noise. The high-voltage power supply provides adjustable high voltage to the detector unit, and the turntable device controller is used for remote control of the detector unit's angle. The data acquisition system power supply provides 100V power to the data acquisition system. In addition to being connected to the front-end circuit board shown in the figure, the data acquisition system is also connected to the HERD trigger subsystem and the TRD host computer. The TRD host computer also needs to be connected to the host computer of the HERD trigger subsystem, in order to initiate data storage upon trigger arrival. Under normal operating conditions, the power consumption of the TRD data acquisition system is 4.3W, and the power consumption of the other sub-modules is 10.3 W. After testing, the TRD data acquisition system was found to meet the requirements of beam experiments. When the trigger is valid, detector data is encoded and transmitted to the host computer without any data loss. Additionally, we conducted long-term uninterrupted operation stability tests, and the test results showed no abnormal occurrences during continuous operation for 30 days.

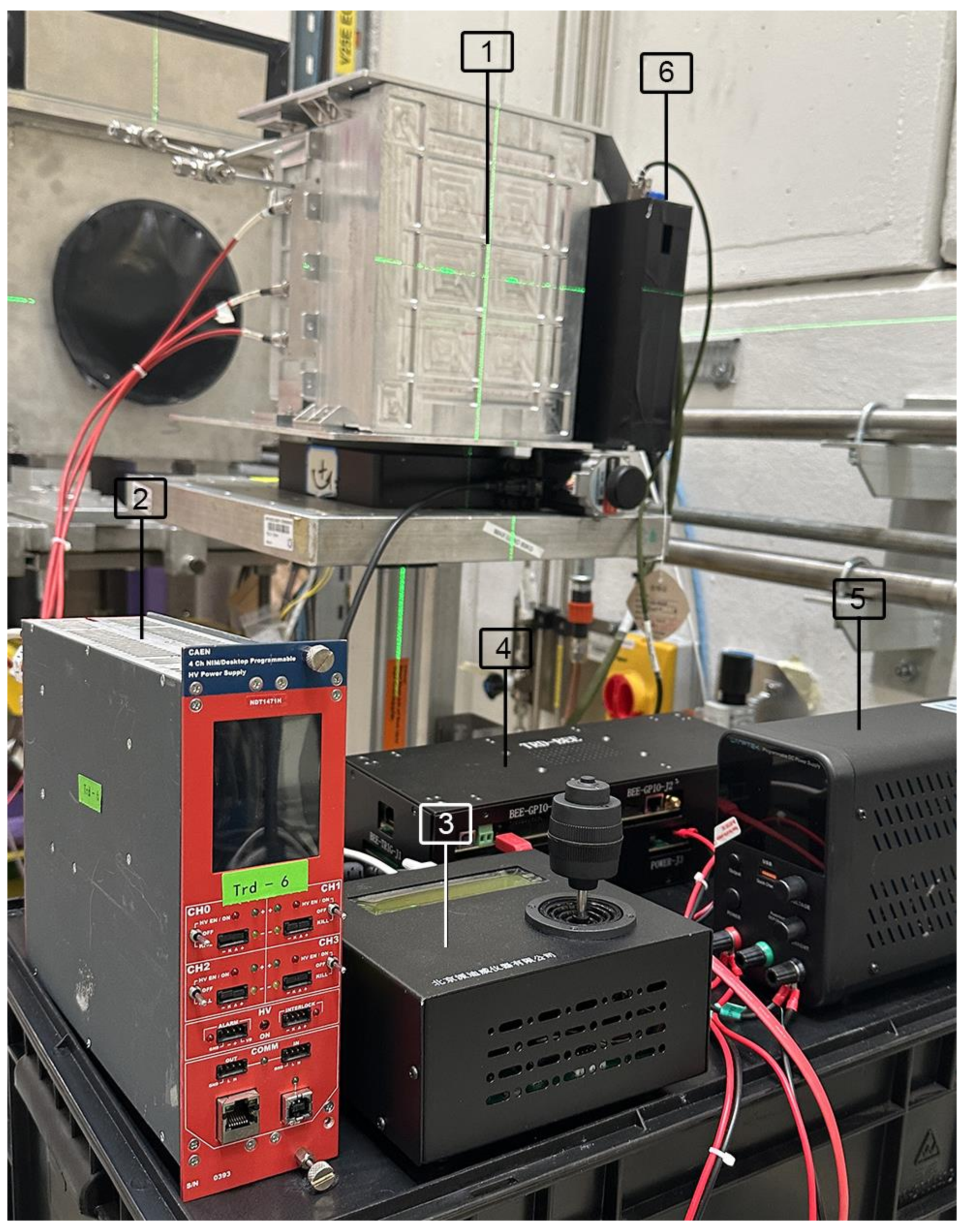

Fig. 3. (1) the detection unit, (2) the high-voltage power supply, (3) the turntable controller, (4) the data acquisition system, (5) the power supply for the data acquisition system, and (6) the front-end circuit board.